# RETRIEVING SEM SAMPLE POSITIONS UNDER LIMITED RELOCATION ACCURACY USING DIGITAL IMAGE PROCESSING

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## Motivation

For many applications of Scanning Electron Microscopy (SEM), it is of high practical relevance to retrieve selected regions-of-interest (ROI) that were identified in previously acquired images. Examples include investigations of specimen with analysis techniques that require different microscopes or working distances. Tasks like a repeated measurement of a ROI to study changes resulting from intermittently applied sample processing steps motivate high accuracy localization techniques. However, the stage relocation accuracy of SEMs is limited by the stage motorization and position control hardware and relocation errors generally exceed a few microns [1].

## SEM Image Acquisition of two epochs

We have developed a SEM control software (TiNa) and implemented an automatic image acquisition workflow (Fig. 1) [1]. It allows autonomous generation of SEM image data with nanoscale resolution. To overcome stage hardware limitations, we have developed a numerical, software-based approach that aligns SEM images with higher than stage relocation accuracy. Its usefulness is demonstrated for imaging the progress of a dry-etching process (Fig. 2 and Fig. 3).

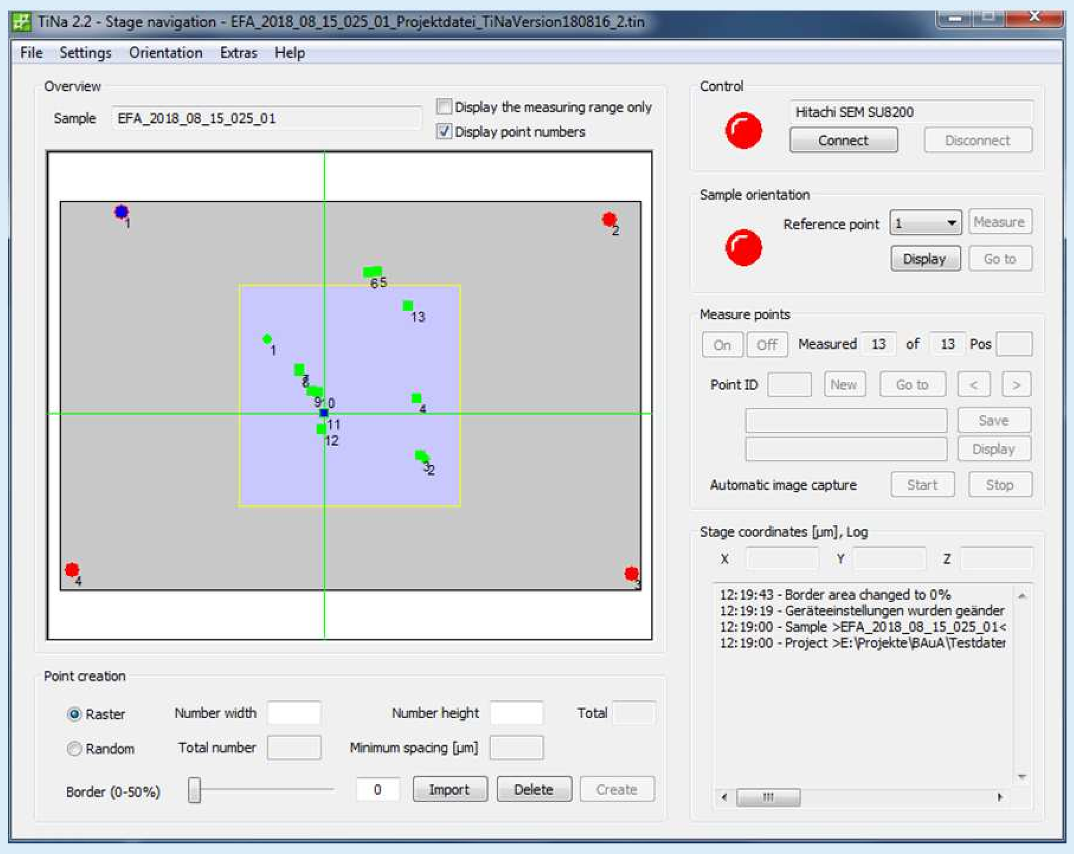

**Fig. 1:** Screenshot of the SEM control software TiNa

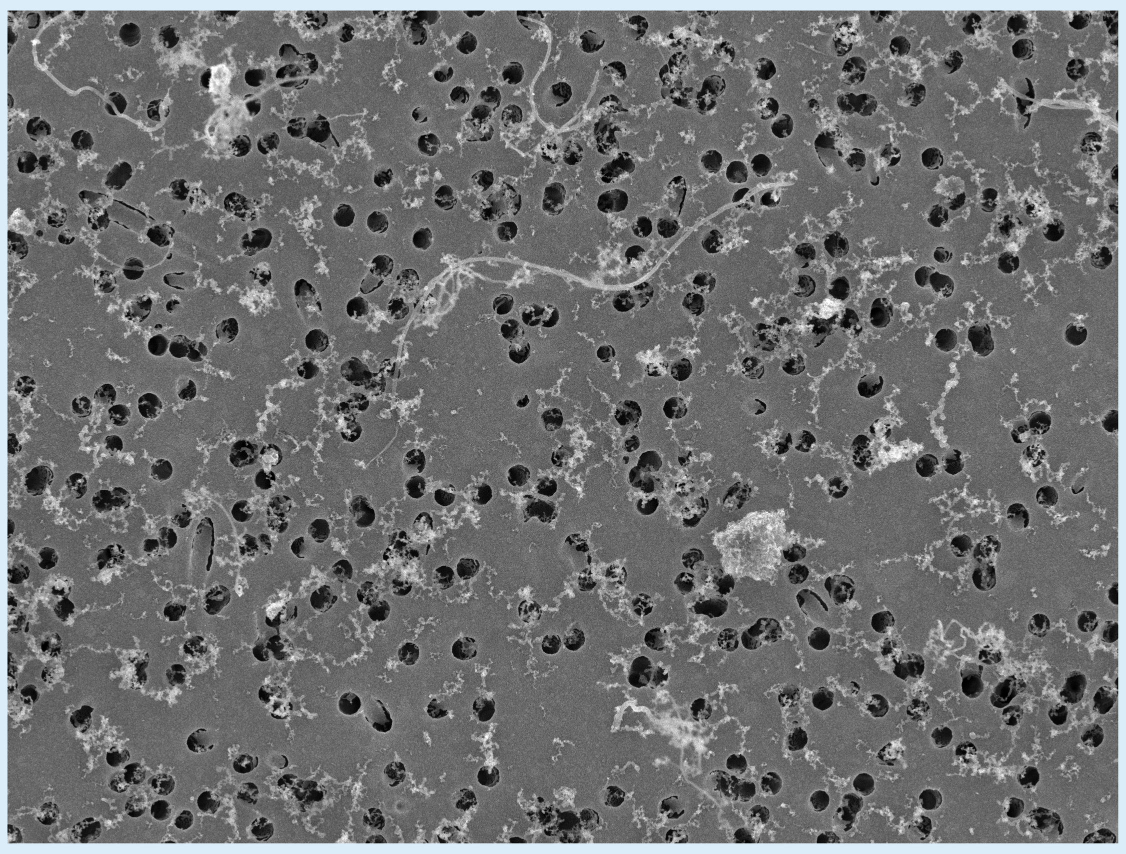

**Fig. 2:** Acquired SEM image of epoch 1

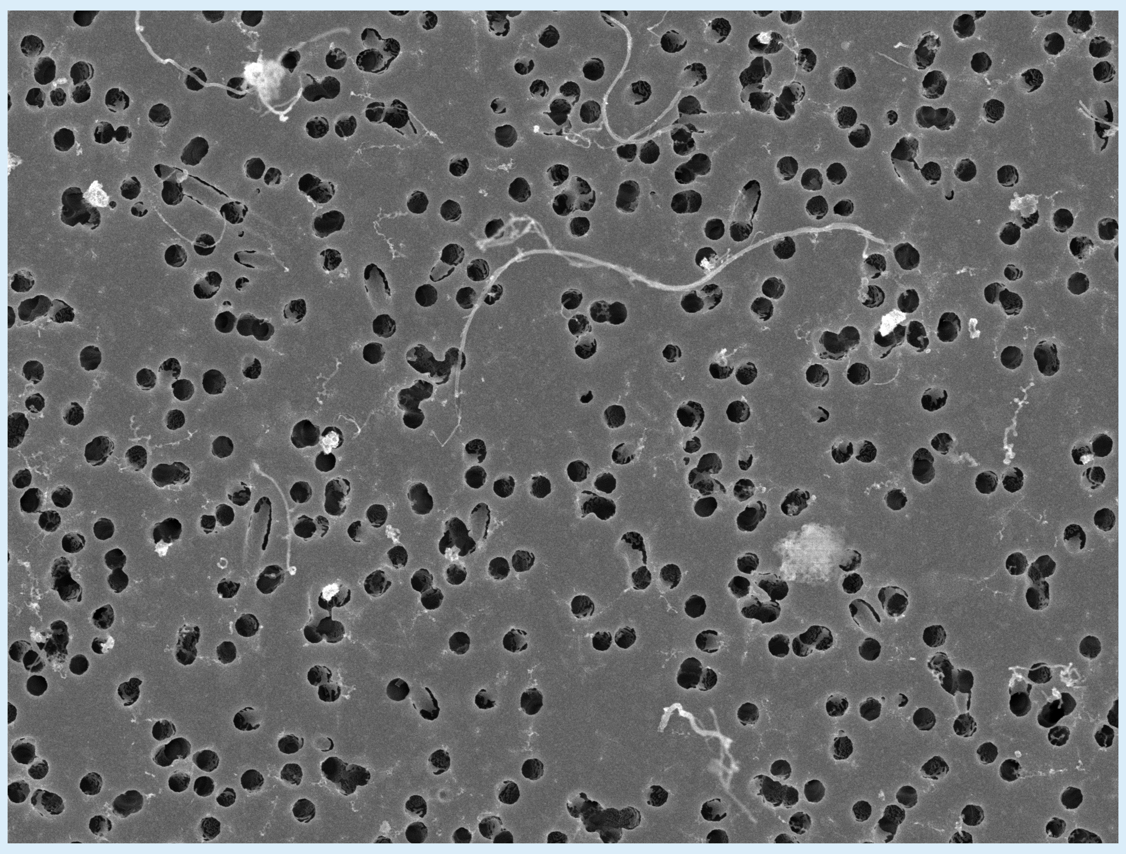

**Fig. 3:** Acquired SEM image of epoch 2

## Automated stage correction and image relocation

TiNa combines mechanical and numerical alignment procedures to optimize ROI retrieval. For this, it starts from previously stored ROI location and image data. It moves the stage to the specified location and acquires a second image. The matching algorithm [2] searches for coinciding characteristic image features in both images afterwards and calculates an affine transformation to connect both image versions. For feature recognition, a Förstner [3] and a self-developed histogram-based approach were studied and implemented.

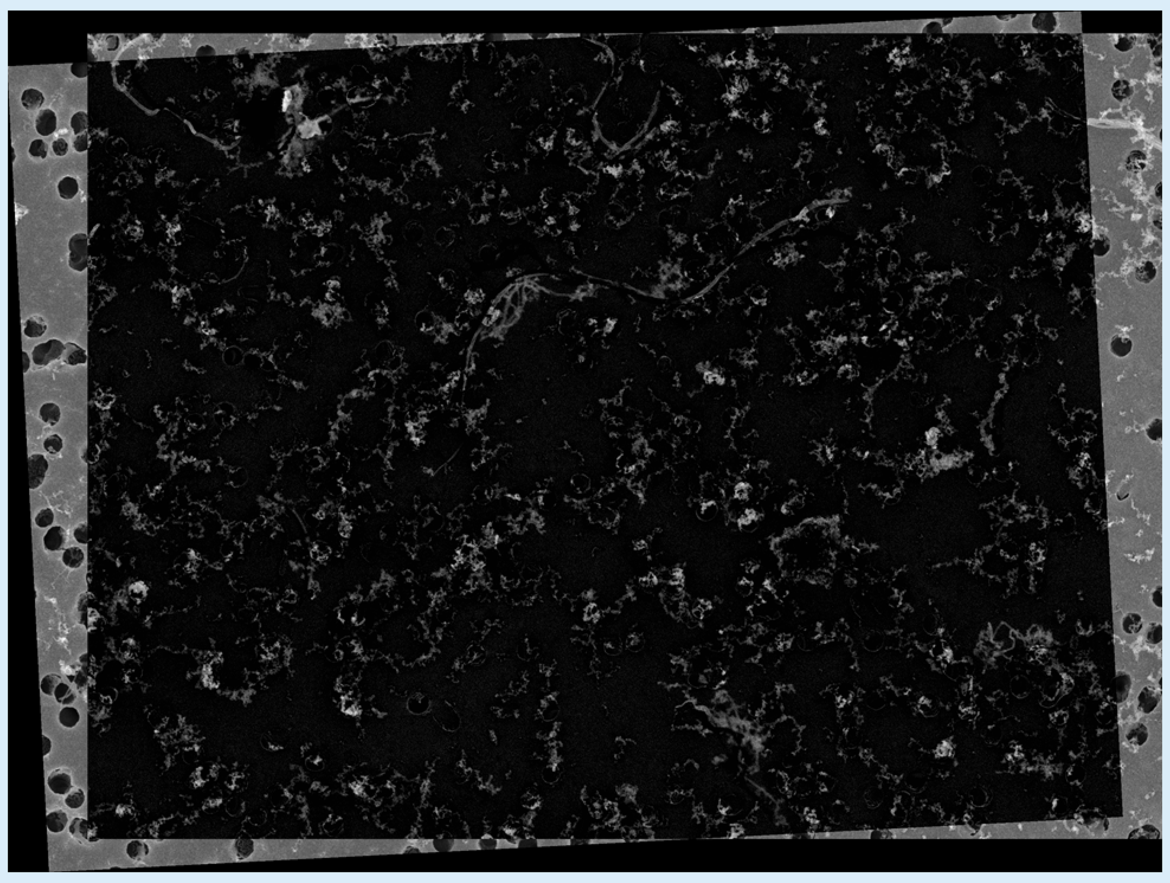

**Fig. 4:** Difference image of the two aligned images after a dry-etching step. A selective removal of soot is revealed.

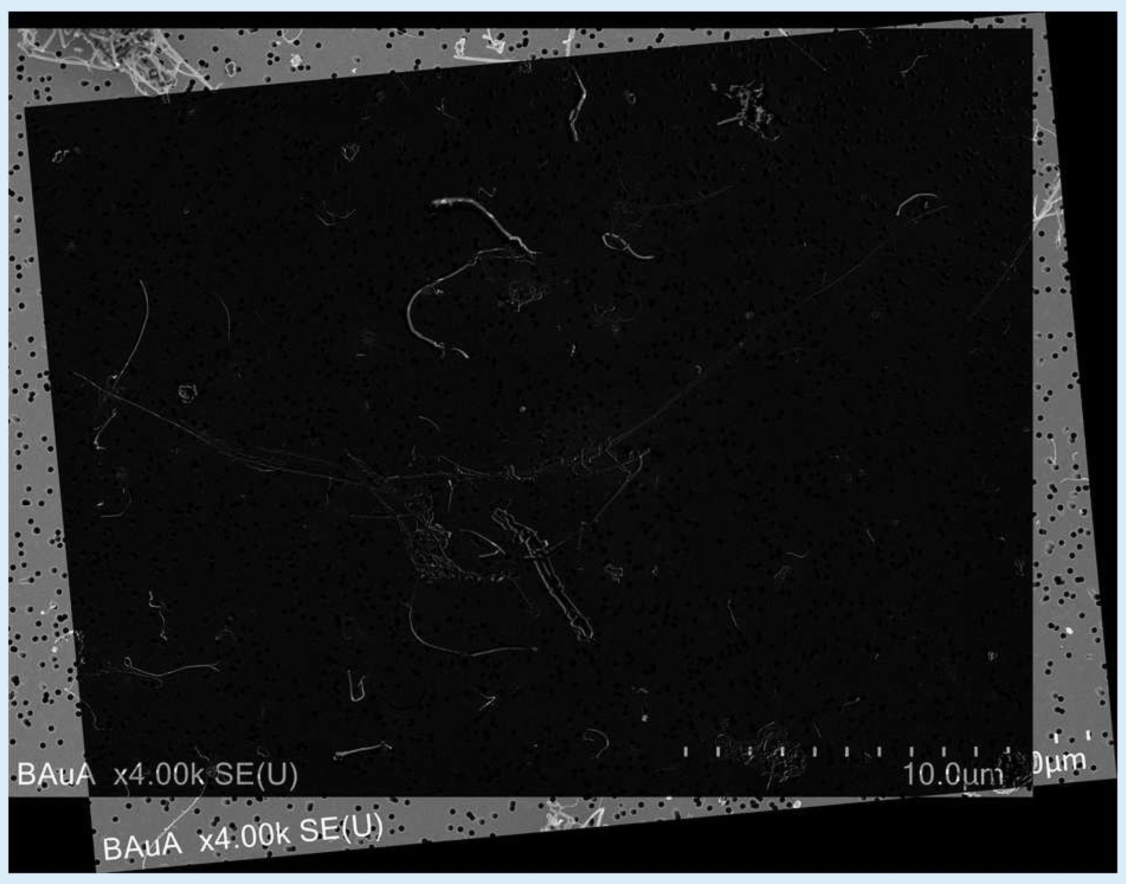


**Fig. 5:** Difference image of two track-etched filter images covered with nanofibres that were aligned numerically.

### Results

The accuracy of numerical image alignment strongly depends on the presence of a sufficiently large number of well-localizable specimen features. The pores of track-etched membranes were well-suited high contrast features. The resulting alignment quality is shown in Fig. 5. It reveals tiniest movements of the nanofibres during successive analysis steps and an excellent alignment of the filter pores. Fig. 4 compares a mixture of nanofibers and soot prior and after a dry-etching step and reveals a selective removal of soot. For these types of images we achieved accuracies well below two pixels.

### Outlook

For retrieved ROIs, additional analysis can be performed for multi-channel specimen information (Fig. 6), e.g. EDS analysis at large working distance combined with very high resolution SEM at short working distance.

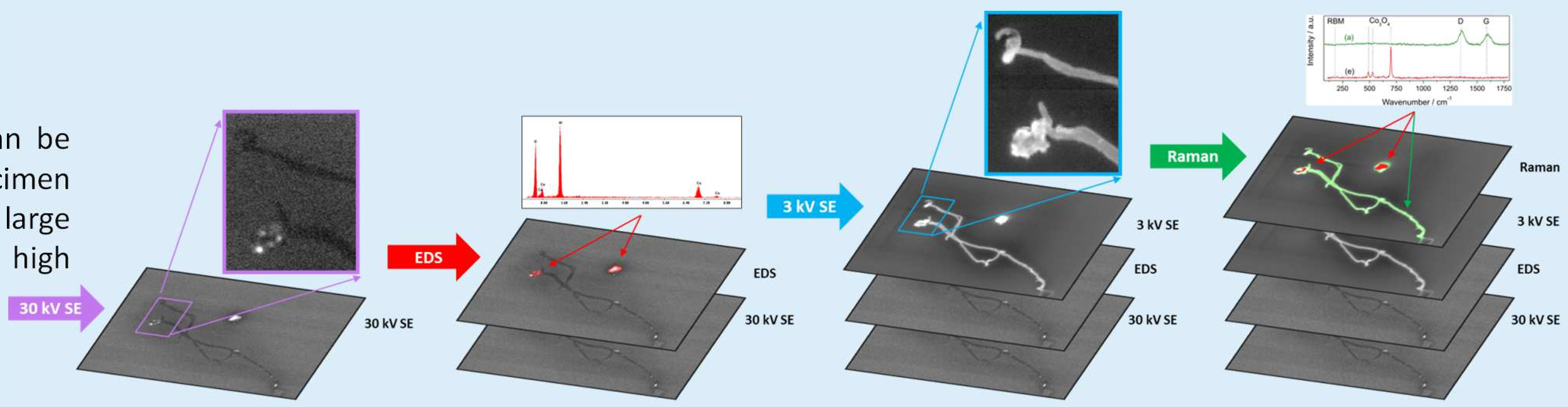


**Fig. 6:** Multi-channel specimen information

### References

[1] Moré et al.: Relocation of defined sample positions with an automated stage navigation tool for SEM. Proceedings of the microscopy conference MC2017 Lausanne, S.481-483.
[2] Ackermann, F.: High Precision Digital Image Correlation. Schriftenreihe Institut für Photogrammetrie, Universität Stuttgart, Heft 9, Stuttgart 1984.
[3] Förstner, W.: A Feature Based Correspondence Algorithm for Image Matching. Proceedings of the Symposium “From Analytical to Digital“, ISPRS Vol.26, Part 3/3, Rovaniemi, Finnland 1986, S.150-166.

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